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A BIOMETRIC COMPARISON OF THE UREDINIOSPORES OF CRONARTIUM RIBICOLA AND CRONARTIUM OCCIDENTALE

BY

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(Contribution from Bureau of Plant Industry)

Reprinted from **JOURNAL OF AGRICULTURAL RESEARCH**

Vol. XXX, No. 3 : : : Washington, D. C., February 1, 1925

PUBLISHED BY AUTHORITY OF THE SECRETARY OF AGRICULTURE, WITH THE COOPERATION OF THE ASSOCIATION OF LAND-GRANT COLLEGES

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1925

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Published semimonthly on the first and fifteenth of each month. This volume will consist of twelve numbers and the Contents and Index.

Subscription price: Domestic, $4.00 a year, two volumes
Single numbers, 20 cents
Foreign, $5.00 a year, two volumes
Single numbers, 25 cents

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A BIOMETRIC COMPARISON OF THE UREDINIOSPORES OF CRONARTIUM RIBICOLA AND CRONARTIUM OCCIDENTALE[1]

By REGINALD H. COLLEY

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INTRODUCTION

It appears to be impracticable to differentiate between *Cronartium ribicola* Fischer and *Cronartium occidentale* Hedgcock, Bethel, and Hunt in the uredinial stage by any ordinary means of visual inspection or low power microscopical examination. Both rusts attack a large number of species of the genus Ribes. Superficially and structurally the uredinia resemble each other very closely; and the urediniospores of the two species differ only slightly—so slightly in fact that the differences escape observation unless special technique is used. The fact that *C. ribicola* is already present in the northwestern United States makes the problem of differentiation something more than a matter of academic interest, on account of the necessity of recognizing advance infections on Ribes.

Hedgcock, Bethel, and Hunt[3] give the size of the urediniospores of *C. occidentale* as 18.5 to 32 by 13.5 to 20μ averaging 24 by 16μ, and state that the wall is 2 to 3μ thick. Colley[4] has described the size of the urediniospores of *C. ribicola* roughly as 19 to 45 by 10 to 20μ. These two range descriptions are not comparable, because the measurements on which the figures are based were not made by similar methods. Granting that they are comparable, however, the range descriptions would not be a sufficiently sound basis for diagnosis, for there is no means of knowing the distribution of the more common spore sizes within the limits of the ranges. Of the many hundreds of spore measurements made on the urediniospores of the two species within the last few years, some have been made on fresh spores and some on dry spores, with and without the use of special mounting media. Obviously these results also are more or less unsatisfactory. The object of this paper is the presentation of an analysis of strictly comparable measurements made on 3,000 urediniospores of each species.

METHODS

SELECTION OF MATERIAL

Herbarium material was selected for the measurement study. Experience had shown clearly that measurements made on fresh spores were not comparable with measurements made on dry spores; and it was obvious that herbarium specimens had one thing at least in common—they were all dry. Furthermore, it was possible to select specimens from the herbarium covering the widest possible range for host, locality, and time of collection. The spores were taken from specimens which appeared to be clean and well preserved, and from sori which appeared to be mature.

The selected specimens were grouped in three series. In each series there were 10 sets of spores—each set consisting of 100 urediniospores of *Cronartium ribicola* and 100 urediniospores of *Cronartium occidentale*. The description of the three series follows:

Field series.—A selection of 50 specimens of each species from collections made in the field; 5 specimens from each species in a set; set numbers 1–10, inclusive.

Block Island series.—A selection of 10 specimens of each species from collections made in experimental plots located on Block Island, off the coast of Rhode Island; one specimen of each species in each set; set numbers 11–20, inclusive.

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[1] Received for publication May 16, 1924; issued April, 1925.

[2] The writer wishes to acknowledge his indebtedness to Dr. George G. Hedgcock, Glenn G. Hahn, and Rush P. Marshall of the Office of Investigations in Forest Pathology, and to Miss Minnie W. Taylor, formerly of the office, for their generous assistance during the course of this study.

[3] HEDGCOCK, G. G., BETHEL, E., and HUNT, N. R. PIÑON BLISTER-RUST. Jour. Agr. Research 14: 411–424, illus. 1918.

[4] COLLEY, R. H. PARASITISM, MORPHOLOGY, AND CYTOLOGY OF CRONARTIUM RIBICOLA. Jour. Agr. Research 15: 619–660, illus. 1918.

Greenhouse series.—A selection of 10 specimens of each species from collections made in the pathological greenhouses at Washington, D. C., one specimen of each species in each set; set numbers 21-30, inclusive.

placed in a small drop of the following medium:[5]

Potassium acetate	10 gms.
Distilled water	500 cc.
Pure glycerine	200 cc.
Ethyl alcohol, 95 per cent	300 cc.
Erythrosin	10 gms.

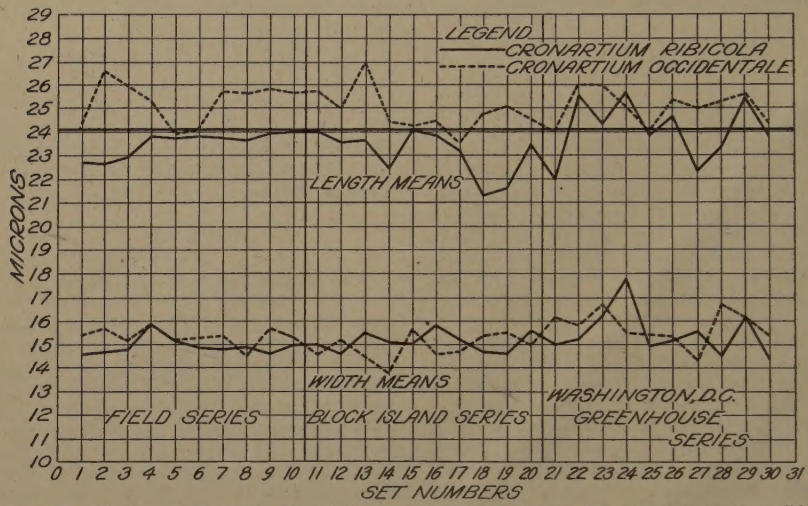

FIG. 1.—Graphs showing the length and width means for 30 sets of urediniospores of *Cronartium ribicola* and *Cronartium occidentale*. Each point on each species line represents the mean of 100 measurements. The series are explained in the text. The set numbers correspond to those in the last columns of Tables I to IV

The collection data are given in full in Tables I to IV.

MOUNTING

The spores were removed from the uredinia as carefully as possible and

They were left in this medium without being covered with a cover glass for several hours. The mount was then finished by adding a drop of glycerine jelly made up as follows:

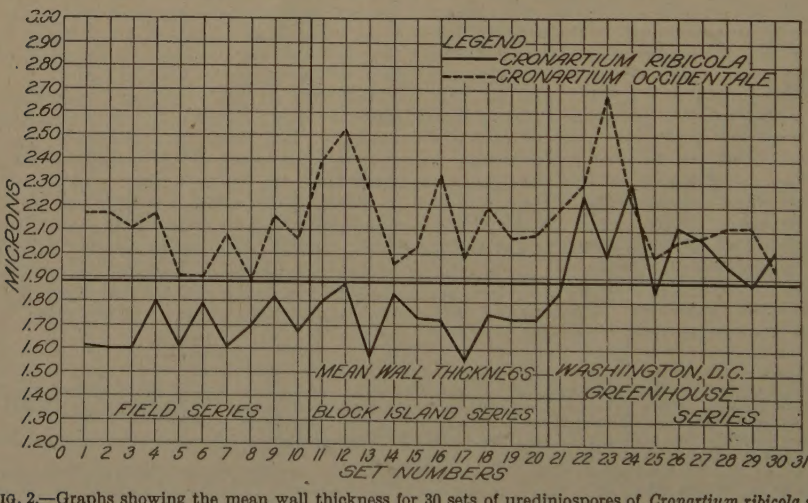

FIG. 2.—Graphs showing the mean wall thickness for 30 sets of urediniospores of *Cronartium ribicola* and *Cronartium occidentale*. Each point on each species line represents the mean of 50 measurements. Series and set numbers as in Figure 1

[5] This medium has been used for years in the Bureau of Plant Industry by Dr C. L. Shear and others. The only modification of their formula is the addition of the erythrosin.

Distilled water	42 cc.
Pure glycerine	50 cc.
Gelatine	7 gms.
Phenol	1 cc.
(Use 1 cc. fresh acid or 1 gm. of crystals.)	
Erythrosin	1 gm. in 9 cc. distilled water

The formula is based on one given by Moreau.[6] The erythrosin should be dissolved as far as possible in the 9 cc. of distilled water and the solution then added to the glycerine gelatine mixture *after* it has been cooked but *before* it has cooled.

MEASURING

All the spores were measured by projection. The apparatus[7] was so arranged that the images of the spores were projected at a magnification of 1,000 diameters on a white field. The images of such spores as fell within a 4-inch circle in this white field were then measured to the nearest millimeter with a standard white-faced millimeter scale. Wall thickness was measured to the nearest half millimeter. The mount was moved across the field of vision systematically by means of a mechanical stage.

In the *Field series* 20 spores were measured from each specimen and the measurements from each 5 specimens grouped at random into sets, as shown in Table I and Table II; but in the *Block Island series* and the *greenhouse series* 100 spores were measured from each specimen. Wall measurements were made on 50 of each 100 spores measured. For each series, therefore, there were 1,000 length measurements, 1,000 width measurements, and 500 wall measurements.

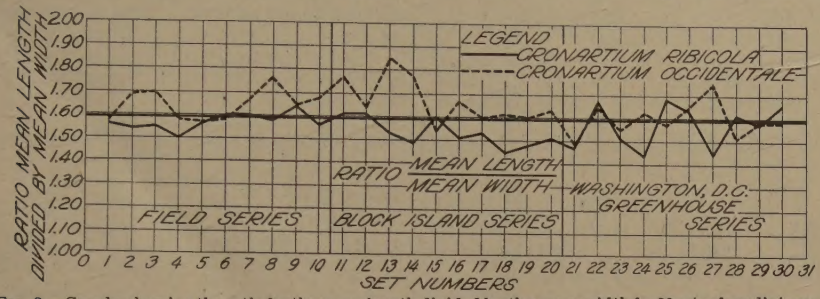

FIG. 3.—Graphs showing the ratio for the mean length divided by the mean width for 30 sets of urediniospores of *Cronartium ribicola* and *Cronartium occidentale*. Series and set numbers as in Figure 1

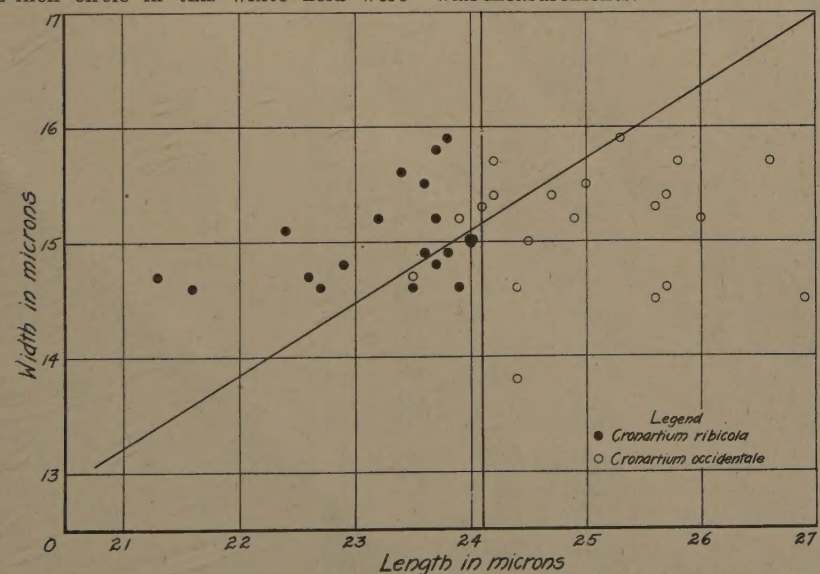

FIG. 4.—Graphic representation of the application of the criteria of size and shape of urediniospores to the biometric diagnosis of *Cronartium ribicola* and *Cronartium occidentale*. Each plotted point represents the length and width mean of 100 measurements. The data are taken from the figures given in Tables I–III for sets 1–20. Further explanation in the text

[6] MOREAU, F. NOTIONS DE TECHNIQUE MICROSCOPIQUE.—APPLICATION Á L'ÉTUDE DES CHAMPIGNONS. Bul. Trimest. Soc. Mycol. France 34; 137–191, illus. 1918.

[7] COLLEY, R. H. A LABORATORY PROJECTION APPARATUS. Phytopathology 14: 424–426, illus. 1924.

ANALYSIS OF THE MEASUREMENT RESULTS

The measurements were tallied and analyzed by ordinary statistical methods. The means for the length and width and wall thickness and the ratio of mean length divided by mean width for each of the 30 sets of spores are given in Tables I to IV. A summary of the measurement data is given in Table V.

The data in Tables I to IV are presented graphically in Figures 1, 2, and 3. Each point on the graphs in Figure 1 represents the mean of the measurements of 100 spores; each point on the graphs in Figure 2 represents the mean of the measurements of the walls of 50 spores; and each point on the graphs in Figure 3 represents the quotient obtained by dividing the mean of the length measurements of 100 spores by the mean of the width measurements of the same spores. The points are connected by the solid line for *Cronartium ribicola* and the broken line for *Cronartium occidentale* in order to facilitate reading.

TABLE I.—*Field series; means for each 100 urediniospores measured; Cronartium ribicola*

Forest pathology No.	Host	Locality	Date collected	Mean length	Mean width	Mean wall thickness	Ratio mean length / mean width	Set No.
2607	Ribes vulgare	Font Hill, Ont.	June 6, 1915	22.7	14.6	1.61	1.56	1
23735	do	North Conway, N. H.	July 4, 1917					
34070	do	Red Bank, N. J.	Aug. 13, 1919					
23870	do	Rochester, N. Y.	Aug. 2, 1917					
22216	do	Chalmers, Mass.	Aug. 11, 1916					
34430	do	Pomroy, Minn.	July 26, 1919					
23105	do	Little Compton, R. I.	Aug. 17, 1916	22.6	14.7	1.60	1.54	2
23205	do	Acton Corner, Me.	Aug. 30, 1916					
23254	Ribes reclinatum	Bar Harbor, Me.	Oct. 2, 1916					
22443	do	Newport, R. I.	Sept. 5, 1916					
2592	do	Lyndonville, Vt.	Sept. 12, 1914	22.9	14.8	1.60	1.55	3
34260	do	Shafer, Minn.	Sept. 29, 1919					
23888	Ribes nigrum	Rochester, N. Y.	Aug. 18, 1917					
23012	do	Warwick, R. I.	July 24, 1916					
23846	do	North Whately, Mass.	July 26, 1917					
34442	do	Cannon City, Minn.	July 30, 1919	23.8	15.9	1.80	1.50	4
23902	do	Tupper Lake, N. Y.	Aug. 22, 1917					
24021	do	Red, Bank, N. J.	Aug. 21, 1918					
20623	do	Font Hill, Ont.	Aug. 13, 1915					
25337	do	Temple, N. H.	June 10, 1919					
23218	do	Limerick, Me.	Sept. 4, 1916	23.7	15.2	1.61	1.56	5
34036	do	Amery, Wis.	July 11, 1919					
23020	Ribes hirtellum	Lyman, Me.	July 25, 1916					
23734	do	Bath, N. H.	July 2, 1917					
34435	Ribes oxyacanthoides.	Pomroy, Minn.	July 28, 1919					
29632	do	Rice Lake, Wis.	Sept. 18, 1918	23.8	14.9	1.79	1.60	6
24043	Ribes cynosbati	West Greenwich, R. I.	Oct. 15, 1918					
24032	do	Bartlett, N. H.	June 13, 1918					
20695	do	Norfolk, Conn.	June 13, 1916					
2606	do	Font Hill, Ont.	June 26, 1915					
23868	do	Stephentown, N. Y.	Aug. 4, 1917	23.7	14.8	1.61	1.60	7
34446	do	Sec. 26, R. 21, Minn.	Aug. 1, 1919					
34103	do	Clear Lake, Wis.	July 23, 1919					
25334	do	Bethel, Vt.	July 6, 1919					
22137	Ribes americanum.	Central Village, Mass.	July 6, 1916					
24045	do	Font Hill, Ont.	June 22, 1917	23.6	14.9	1.70	1.58	8
23764	do	St. Johnsbury, Vt.	July 20, 1917					
34235	do	Munch Township, Minn.	Sept. 21, 1919					
34537	do	Downing, Wis.	Aug. 26, 1919					
22165	Ribes glandulosum.	Norfolk, Conn.	July 3, 1916					
23859	do	Bartlett, N. H.	July 28, 1917	23.9	14.6	1.82	1.64	9
28232	do	Brunswick, Me.	May 22, 1918					
23877	do	North Thetford, Vt.	Aug. 7, 1917					
24321	do	Amery, Wis.	Aug. 11, 1916					
24019	Ribes triste	Tuckerman Ravine, N. H.	Aug. 3, 1918					
23365	do	Rush Lake, Minn.	June 14, 1918	24.0	15.0	1.68	1.56	10
34095	Ribes odoratum	Petersham, Mass.	July 30, 1919					
23125	do	Kittery, Me.	Aug. 18, 1916					
23834	do	Keeseville, N. Y.	July 24, 1917					
23798	do	Orford, N. H.	July 11, 1917					

TABLE II.—*Field series; means for each 100 urediniospores measured; Cronartium occidentale*

Forest pathology No.	Host	Locality	Date collected	Mean length	Mean width	Mean wall thickness	Ratio mean length / mean width	Set No.
27029	Ribes aureum	Farmington, N. Mex.	Sept. 9, 1918	24.2	15.4	2.17	1.57	1
27033	do	Aztec, N. Mex.	Sept. 10, 1918					
27151	do	Clayton, N. Mex.	Sept. 26, 1919					
27154	do	Farmington, N. Mex.	Aug. 2, 1919					
29087	do	Miller Valley, Ariz.	Oct. 6, 1917					
28218	do	Monrovia, Calif.	May —, 1919	26.6	15.7	2.17	1 69	2
28275	do	do	May 13, 1919					
29518	do	Morgan, Utah	Aug. 24, 1920					
29519	do	Iron Co., Utah	July 30, 1920					
26475	Ribes odoratum	Prescott, Ariz.	Oct. 2, 1917	26.0	15.2	2.11	1.70	3
29515	Ribes aureum	Fillmore, Utah	Aug. 7, 1920					
29516	do	Hygrum, Utah	Aug. 22, 1920					
29517	do	Scipio, Utah	Aug. 10, 1920					
36221	do	Iron Co., Utah	July 30, 1920					
36222	do	Beaver, Utah	Aug. 3, 1920					
27100	do	Hayden, Colo.	Oct. 18, 1918	25.3	15.9	2.17	1.58	4
26159	do	Meeker, Colo.	Oct. 2, 1917					
27046	do	Trimble Hot Springs, Colo.	Sept. 14, 1918					
27047	do	Hermosa, Colo.	Sept. 15, 1918					
27049	do	Durango, Colo.	Sept. 15, 1918					
32707	Grossularia velutina.	Mono Lake, Calif.	Aug. 20, 1919	23.9	15.2	1.91	1.57	5
34076	Ribes aureum	Bridgeport, Calif.	Aug. 2, 1919					
36621	Ribes gracillimum.	do	Aug. 20, 1919					
34019	Grossularia inermis.	Denver, Colo.	July 1, 1919					
34020	do	do	July 1, 1919					
29525	do	Monticello, Utah	Aug. 15, 1918	24.1	15.3	1.90	1.58	6
29654	Grossularia reclinata.	Mancos, Colo.	Sept. 12, 1918					
22644	do	Prescott, Ariz.	Oct. 27, 1917					
29392	do	Mancos, Colo.	July 31, 1918					
26745	Ribes aureum	Pagoro Springs, Colo.	Sept. —, 1917					
22648	Ribes odoratum	Prescott, Ariz.	Oct. 29, 1917	25.7	15.4	2.08	1.67	7
22635	do	do	Oct. 27, 1917					
29463	do	Mancos, Colo.	Aug. 9, 1918					
22634	Ribes aureum	Prescott, Ariz.	Oct. 27, 1917					
36112	do	Monrovia, Calif.	June 15, 1920					
28294	Ribes gracillimum.	Monrovia, Calif.	June 25, 1919					
28277	Ribes aureum	do	May 18, 1919	25.6	14.5	1.89	1.76	8
28276	do	do	May 17, 1919					
23396	do	do	May 22, 1919					
25054	Ribes odoratum	do	Oct. 27, 1919					
26485	Ribes aureum	Naturita, Colo.	Aug. 18, 1917	25.8	15.7	2.16	1.65	9
26499	do	Denver, Colo.	Sept. 25, 1917					
27101	do	Craig, Colo.	Oct. 18, 1918					
27039	do	La Plata, Colo.	Sept. 11, 1918					
36059	do	Monrovia, Calif.	Feb. 25, 1919					
2859	do	Boulder, Colo.	July —, 1914					
24648	do	Ute Reservation, Colo.	July —, 1897	25.6	15.3	2.06	1.68	10
22618	do	Bayfield, Colo.	Aug. 26, 1917					
24420	do	do	Sept. 15, 1917					
36089	do	Monrovia, Calif.	June 14, 1920					

TABLE III.—*Block Island series; means for each 100 urediniospores measured; Cronartium ribicola and Cronartium occidentale*

CRONARTIUM RIBICOLA

Forest pathology No.	Host	Locality	Date collected	Mean length	Mean width	Mean wall thickness	Ratio mean length / mean width	Set No.
34555	Ribes odoratum	Block Island, R. I.	June 22, 1920	24.0	15.0	1.80	1.61	11
34556	do	do	June 22, 1920	23.5	14.6	1.87	1.61	12
34579	do	do	July 20, 1920	23.6	15.5	1.57	1.53	13
34622	do	do	Sept. 8, 1920	22.4	15.1	1.83	1.49	14
34878	do	do	Sept. 30, 1920	24.0	15.0	1.74	1.60	15
34881	do	do	Sept. 30, 1920	23.8	15.8	1.73	1.51	16
34558	Ribes nigrum (Naples).	do	June 22, 1920	23.2	15.2	1.56	1.53	17
34619	do	do	Sept. 8, 1920	21.3	14.7	1.75	1.45	18
34888	Ribes americanum.	do	Sept. 30, 1920	21.6	14.6	1.73	1.48	19
34880	Ribes prostratum.	do	Sept. 30, 1920	23.4	15.6	1.73	1.51	20

CRONARTIUM OCCIDENTALE

34568	Ribes odoratum	Block Island, R. I.	June 23, 1920	25.7	14.6	2.39	1.77	11
34574	do	do	June 30, 1920	24.9	15.2	2.52	1.64	12
34630	do	do	Sept. 9, 1920	26.9	14.5	2.26	1.85	13
34634	do	do	Sept. 9, 1920	24.4	13.8	1.96	1.77	14
34846	do	do	Sept. 9, 1920	24.2	15.7	2.03	1.54	15
34877	do	do	Oct. 1, 1920	24.4	14.6	2.34	1.67	16
34627	Ribes nigrum (Naples).	do	Sept. 9, 1920	23.5	14.7	1.99	1.60	17
34871	do	do	Oct. 1, 1920	24.7	15.4	2.20	1.61	18
34647	Ribes americanum.	do	Sept. 9, 1920	25.0	15.5	2.07	1.60	19
34633	Ribes prostratum.	do	Sept. 9, 1920	24.5	15.0	2.08	1.63	20

TABLE IV.—*Washington, D. C., greenhouse series; means for each 100 urediniospores measured; Cronartium ribicola and Cronartium occidentale*

CRONARTIUM RIBICOLA

Forest pathology No.	Host	Locality	Date collected	Mean length	Mean width	Mean wall thickness	Ratio mean length / mean width	Set No.
34684	Ribes aureum	Washington, D. C.	July 15, 1920	22.0	15.0	1.84	1.47	21
34697	do	do	Aug. 2, 1920	25.5	15.2	2.24	1.67	22
34722	do	do	Aug. 25, 1920	24.3	16.1	1.99	1.51	23
34826	do	do	Oct. 8, 1920	25.6	17.7	2.29	1.44	24
36466	do	do	July 21, 1920	23.8	14.9	1.84	1.68	25
34712	do	do	Aug. 11, 1920	24.6	15.1	2.11	1.63	26
34740	do	do	Aug. 4, 1920	22.3	15.5	2.06	1.44	27
36125	do	do	July 8, 1920	23.3	14.5	1.95	1.61	28
36465	do	do	Aug. 9, 1920	25.4	16.1	1.87	1.57	29
36470	do	do	Aug. 9, 1920	23.7	14.3	2.01	1.66	30

CRONARTIUM OCCIDENTALE

36104	Ribes aureum	Washington, D. C.	July 1, 1920	24.0	16.1	2.19	1.49	21
36150	do	do	July 2, 1920	26.0	15.8	2.29	1.65	22
36233	do	do	Aug. 17, 1920	25.9	16.7	2.66	1.55	23
36406	do	do	May 22, 1920	25.0	15.5	2.22	1.62	24
36439	do	do	Aug. 2, 1920	24.0	15.4	1.99	1.57	25
36446	do	do	Aug. 9, 1920	25.3	15.3	2.05	1.65	26
36078	do	do	July 8, 1920	24.9	14.3	2.07	1.75	27
36131	do	do	July 14, 1920	25.2	16.7	2.11	1.51	28
36404	do	do	June 22, 1920	25.5	16.1	2.11	1.58	29
36429	do	do	June 9, 1920	24.2	15.3	1.93	1.58	30

TABLE V.—*Summary of measurement data; urediniospores of Cronartium ribicola and Cronartium occidentale*

Species	Length [a]			Width			Mean [b] wall thickness	Ratio mean length / mean width
	Mean length	Standard deviation	Coefficient of variability	Mean width	Standard deviation	Coefficient of variability		
Field series:								
Cronartium ribicola	23.5	2.6	11.1	15.0	1.8	12.1	1.70	1.57
Cronartium occidentale	25.2	3.5	13.7	15.3	1.8	11.4	2.05	1.64
Block Island series:								
Cronartium ribicola	23.1	2.6	11.3	15.1	1.6	10.8	1.73	1.53
Cronartium occidentale	24.9	2.9	11.8	14.9	1.7	11.5	2.18	1.67
Washington, D. C., greenhouse series:								
Cronartium ribicola	24.1	3.4	13.9	15.4	2.0	12.9	2.02	1.57
Cronartium occidentale	25.0	3.1	12.3	15.7	1.9	12.0	2.16	1.60

[a] The length and width means are based on 1,000 measurements for each species in each series.
[b] The mean wall thickness is based on 500 measurements for each species in each series.

DISCUSSION

Each of the three series of measurements serves a different purpose; for the mean measurements of the sets in the *Field series* evidently are better species indices than those in the two other sets, being based on a broader sampling system; and the means in the *Block Island series* show the difference in size of the urediniospores of the two species on a few Ribes hosts growing in the same locality, as well as the practical utility of 100 spore means for diagnostic purposes; whereas the means in the *Greenhouse series* represent the variation in the urediniospores of the two species on the same host (*Ribes aureum*) grown under experimental conditions in the greenhouse.

It is evident from the graphs of the length means and wall thicknesses that the two species are distinct, as far as these two factors are concerned, in the *Field series* and *Block Island series*, but that they are not separable on the same bases in the *Greenhouse series*. The respective value of the measurements for diagnostic purposes appears to be in the order of length mean, mean wall thickness, and ratio of mean length divided by mean width. The width mean has no diagnostic value. The results indicate that measurements of the urediniospores from hosts growing in the greenhouse should be used with extreme caution, if at all, in any attempt to diagnose field collections of either species. The data obtained in the *Field series* and the *Block Island series*, however, appear to warrant the conclusion that field collections can be separated in most cases on the basis of spore size, spore shape, and wall thickness. The following discussion of diagnostic division points is accordingly confined to the data from sets 1–20 inclusive.

The horizontal line drawn at 24.1μ, in Figure 1, separates 37 out of the 40 length means correctly, all 20 means for *C. ribicola* being below the line and 17 means for *C. occidentale* being above the line. One mean for *C. occidentale* falls on the line.

The horizontal line drawn at 1.88μ, in Figure 2, separates all 40 of the mean wall thicknesses correctly, the 20 for *C. ribicola* being below the line and the 20 for *C. occidentale* being above the line.

The horizontal line drawn at 1.59, in Figure 3, separates 29 out of 40 of the ratios of mean length divided by mean width correctly, 14 out of 20 for *C. ribicola* being below the line and 15 out of 20 for *C. occidentale* being above the line.

In other words the diagnostic division points,

24.1 for the length mean,
1.88 for the mean wall thickness,
and
1.59 for the ratio of mean length divided by mean width,

would have correctly identified 92.5 per cent, 100 per cent, and 72.5 per cent, respectively, of the sets measured.

Examination of the graphs shows that the measurements for *C. occidentale* in set 5 are abnormal, that is, on the wrong side of the diagnostic division points for both length mean and ratio; that the figures are low for the length mean of the same species in set 6, low for the wall mean in sets 5 and 6, and below the line for the ratio in set 6. However, there is not a single case where the figures for any one set for either species fall on the wrong side of the line for all three criteria, and only one case, the one in set 5 men-

tioned above, where the figures fall on the wrong side for two criteria. On account of the greater irregularity in the ratio figures, a variation above or below the line is of less importance than a similar variation in length or wall thickness mean. If the two latter criteria only are considered there are but 2 means out of 40 which are definitely out of line—the length means for *C. occidentale* in sets 5 and 17—which makes the biometric diagnosis correct in 95 per cent of the trails.

The relation of the means of sets 1 to 20 to the diagnostic division points for the length mean and for the ratio of mean length divided by mean width is shown again in Figure 4, a type of figure which appears to be particularly satisfactory for illustrating the application of the criteria of size and shape to biometric diagnosis. Each of the plotted points represents both the mean length and mean width of 100 measurements. The means for *C. ribicola* are shown as dots and the means for *C. occidentale* are shown as circles. Set numbers have been omitted purposely, but the position of the means for any set can be found by reference to the mean values given in Tables I to III. For example, the means for set 1 are indicated by the dot and circle at 22.7 and 14.6, and at 24.2 and 15.4, respectively.

The diagnostic division point for the length mean, represented by the horizontal line drawn at 24.1 in Figure 1, is here represented as a vertical line at 24.1. The diagonal line, drawn to satisfy the equation $y=\frac{x}{1.59}$, represents the diagnostic division point for mean length divided by mean width. The figure illustrates clearly the "scatter" or shotgun pattern of the mean sizes for each of the 100's measured, the fact that length is the factor governing the distribution of the points to the left or right of the 24.1 line, and the effect of variation in size on the position of the plotted points with respect to the diagonal.

The difference between the 1,000 spore length means of the two species (see Table V) for the *Field series* is 1.76 ± 0.092, for the *Block Island series* 1.82 ± 0.072, and for the *Greenhouse series* 0.81 ± 0.099. No attempt will be made at present to establish the significance of these differences with respect to their probable errors, since it seems preferable to leave any such discussion as well as a more detailed description of the mounting measuring and analysis methods to a later paper.

The ranges for the spore sizes of the two species are given in Table VI. It is obviously impossible to separate the species on the basis of the range of the spore sizes. Ranges obtained by subtracting and adding the standard deviation to the mean for each dimension—which might be called "standard ranges"—are, however, more significant. These ranges in the three series are given in Table VII. In spite of the fact that the standard ranges are much more accurate indices of the spore sizes than the complete ranges, they do not serve to bring out the differences between the species as clearly as the tabular or graphic representation of the means.

It must be admitted after examination of the graphs in Figures 1 and 2 that *C. ribicola* and not *C. occidentale* is the species which appears to be "abnormal" under greenhouse conditions. No adequate explanation of the "abnormality" is possible at present.

In the *Field series* the measurements of 5 lots of 20 spores each were grouped together, as has been previously stated,

TABLE VI.—*Ranges for length and width of the urediniospores of Cronartium ribicola and Cronartium occidentale*

Series	C. ribicola		C. occidentale	
	Length	Width	Length	Width
Field	16–34	10–22	16–37	10–21
Block Island	13–32	10–21	18–37	10–22
Greenhouse	15–40	10–24	16–39	10–23

TABLE VII.—*Standard ranges for the length and width of urediniospores of Cronartium ribicola and Cronartium occidentale*

Series	C. ribicola		C. occidentale	
	Length	Width	Length	Width
Field	20. 9–26. 1	13. 2–16. 8	21. 7–28. 7	13. 5–17. 1
Block Island	20. 5–25. 7	13. 5–16. 7	22. 0–27. 8	13. 2–16. 6
Greenhouse	20. 7–27. 5	13. 4–17. 4	21. 6–28. 4	13. 5–17. 3

and the means for length and width illustrated in Figure 1 were based on the resultant 100's. This procedure undoubtedly resulted in a set of means showing less variation than would be expected if the means had been based on the measurements of 100 spores from single specimens, in which case there would have been more danger of crossing the dead line 24.1. The points on the graph for the length means of sets 1–10 in the *Field series* are, therefore, not exactly comparable with the points for sets 11–20 in the *Block Island series*. As a matter of fact, the *Block Island series* is the only one of the three which illustrates the way in which biometric diagnosis methods based on measurements of 100 spores might work out when applied to unknowns.

The data indicate that 200 measurements would have been better than 100 as a basis for determining the means; and, in cases where the species are close together as these rusts are, it would seem wiser to use the higher number. Means based on 200 measurements would probably have shown less tendency to cross the diagnostic division point than the means based on 100 measurements.

It would be preferable also in diagnosing unknown specimens to take spores from as many different leaves or sori as possible for each specimen studied; in other words, to sample the specimen with the aim of getting the best possible representative lot of spores for the mount. Unfortunately it was not practicable to follow this course in all the cases reported in this paper.

The following examples indicate the futility of attempts to use measurements of fresh spores as size standards, particularly in the case of *C. ribicola*, unless, of course, they are to be compared with other measurements made on fresh spores. The mean measurements for 137 fresh urediniospores of *C. ribicola* from *Ribes gracillimum*, mounted in water, were found to be 28.7 by 18.4, with a standard range of approximately 25 to 33 by 16 to 23μ. The walls of this set were not measured. The means of 50 fresh urediniospores, mounted in water, from a specimen collected on *Ribes aureum* growing in the greenhouse were 33.2 by 21.5μ, with a standard range of approximately 30 to 37 by 20 to 24μ. The mean wall thickness was 0.91μ. These means and standard ranges are far out of line with the figures given in the tables for *C. ribicola*. On the other hand the means for 330 urediniospores from herbarium specimens of *C. ribicola* collected in the field on various hosts were 22.3 by 15.4μ, with a standard range of 18 to 27 by 13 to 18μ. The mean wall thickness was approximately 2.00μ. These figures agree fairly well with those for sets 1, 2, and 3 of *C. ribicola* in Table I, except for the wall mean; yet the results are not really comparable, except in a very general way, because the measurements were made some years ago by methods which were not comparable with those used by the writer.

On the basis of the data presented, it would be going too far to expect biometric diagnosis methods to yield 100 per cent correct results; but they are the only methods applicable in cases where one is dealing with herbarium material, and where inoculation experiments are impossible. The diagnostic division points given in this paper can not be expected to hold good unless the mounting methods are rigidly followed. The measuring must be done with great care—as all real measuring should be done—and the measurements should be analyzed by statistical methods. Under such conditions the investigator can separate the uredinial stages of *C. ribicola* and *C. occidentale* in most cases with comparative ease.

In a later paper a biometric comparison of the aeciospores of the two species will be presented.

SUMMARY

The above analysis of measurements on 3,000 urediniospores of *Cronartium ribicola* and *Cronartium occidentale* indicates that the two species may be separated in the uredinial stage with practical certainty on the basis of spore size, shape, and wall thickness.

The most important criteria for biometric diagnosis are the length mean, the mean wall thickness, and the ratio of mean length divided by mean width.

The diagnostic division point for the length mean is 24.1μ, for the mean wall thickness 1.88μ, and for the ratio of mean length to mean width 1.59.

In the cases of collections from the field and from experimental plots these three diagnostic division points proved good in 92.5 per cent, 100 per cent, and 72.5 per cent, respectively, of the trials.

The dimensions of urediniospores produced under greenhouse experimental conditions do not appear useful for distinguishing these two species.

The data presented in the paper are applicable only when the conditions of mounting, measuring, and analysis are strictly comparable.